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HUGHES AIRCRAFT COMPANY
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MATERIALS TECHNOLOGY DEPARTMENT
Culver City, California

RIGIDIZED INFLATABLE SOLAR ENERGY CONCENTRATORS

Period of November 1963 to February 1964

by

S. Schwartz

SECOND QUARTERLY PROGRESS REPORT

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APPROVED: W. H. Colner

W. H. Colner, Manager
Materials Technology Department

Hughes Aircraft Company · Culver City, California

FOREWORD

This quarterly report was prepared by the Materials Technology Department at Hughes Aircraft Company under NASA Contract NAS 1-3244. The work being done consists of a development of a technique for rigidization of an inflatable parabolic collector in a space environment. This contract is administered under the direction of the Erectable Structures Branch of the Structures Research Division, Langley Research Center, with Mr. Atwood Heath serving as Technical Representative.

This report covers work from the period 1 November 1963 to 1 February 1964.

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The investigation of various gel coat materials, started during the first quarter, was continued. Gel coats investigated included polysulfides, epoxy-polyamides, epoxy-polysulfides, urethanes and thin coatings of polyester resin.

A number of tests were made to attempt to determine the causes for optical distortion, and possible means of minimizing the distortion. Distortion was found to be definitely related to degree and rate of cure of the rigidizing resin and was also related to use of a fabric reinforcement. Epoxy resins appeared to show less distortion than did polyesters. Incorporation of a powdered filler instead of fabric, particularly hollow, phenolic microballoons, resulted in much improved optics. Techniques of evenly distributing a microballoon filled resin (a syntactic foam) over a relatively large surface remain a problem. Author

INTRODUCTION

The principal objective of this program is to develop a technique for fabrication of a solar energy collector for use in a space environment. This collector should be fabricated as a compact package on earth and should be capable of automatic inflation and rigidization in a space environment. The collector is to be made in a lenticular shape, one surface utilizing an aluminized Mylar film as the reflector, and the other surface a clear plastic to act simply as a pressurization member. After inflation to the desired shape the reflective surface would be rigidized by a pre-applied coating.

Preliminary tests of an ultraviolet radiation catalyzed polyester-fiberglass rigidizing system indicated that this concept appeared feasible. The major problems in fabricating the paraboloid appear to be: (1) production of a satisfactory bond from the rigid laminate to the Mylar film, (2) obtaining a satisfactory optical surface on the aluminized Mylar and (3) obtaining a satisfactory figure in the formed and rigidized Mylar.

In the work done during the first quarter of the project it appeared that techniques could readily be devised to obtain a satisfactory bond to the Mylar. The optical surface produced by these techniques, however, was far from satisfactory in the preliminary tests. The major portion of this quarterly effort then was devoted to determining the causes for the poor optics and developing fabrication processes to improve the optics. The work was mainly concerned with investigations into various gel coats and the use of transparent fixtures to allow observation of the rigidizing parabolas during cure.

GEL COAT INVESTIGATIONS

POLYSULFIDES

The first preliminary tests which were made demonstrated the need for a gel coat. The coating served as a primer to improve adhesion of the reinforcement and helped to compensate for the shrinkage effects of the polyester-fiberglass laminate. In preliminary testing a number of different types of materials as gel coats polysulfide based coatings appeared to be superior from the standpoint of adhesion to Mylar and good flexibility. A number of commercially available coating materials were therefore procured so that comparison tests could be made.

The materials procured for test are shown in Table I. In each case the sample was procured in a brushing or spraying viscosity.

Identification	Source
CS-3414	Chem Seal Corporation
890B	Coast Pro-Seal Products
EC-801	Minnesota Mining and Manufacturing Company
EC-1239	Minnesota Mining and Manufacturing Company

Table I. Polysulfide gel coat materials.

Each material was tested by brushing one coat or spraying four thin coats on the outer surface of a six-inch diameter inflated diaphragm. The tests were all made using transparent test fixtures so that the optical effect of each coating might be observed as the material cured. In all cases uniformly good optics were obtained with the exception of several heavily applied brush coats. In these tests, with the heavy coatings, slight optical distortions in the form of brush marks were evidenced. Tests were also made using one and two foot inflated diaphragms with similar results. These tests then indicated that very little distortion resulted on application of the gel coat, with the exception of heavy brushed coats.

There was little difference between any of the polysulfide coatings. Each appeared to have good adhesion to the Mylar and showed good flexibility when cured. The adhesion of the polyester resin to the polysulfide coating, however, was uniformly poor unless a fabric lock coat was used. The materials did differ somewhat in initial viscosity and general workability and in this respect the EC-801 coating made by the Minnesota Mining and Manufacturing Company was selected as best.

EPOXY-POLYAMIDES

Since the polysulfides were not considered entirely satisfactory from the standpoint of adhesion to the polyester layer several epoxy-polyamide mixtures were also tested. The first mixture tested was as follows:

Union Carbide Epoxy ERL-2795	30 pts
General Mills Versamid 125	70 pts
Cab-O-Sil	5 pts

Fair to good adhesion to the Mylar was achieved and fair adhesion to the polyester resulted. The optical surface, however, was poor. The surface, while not showing a fabric pattern, did have a fine "orange peel" effect. A 50-50 epoxy-Versamid mixture was somewhat less flexible than the 70-30 mixture but did show a finer "orange peel" surface. Later samples were made using 40 parts of epoxy resin to 60 parts of Versamid. This formulation appeared to result in approximately the same optics, or slightly superior optics to the 50-50 mixture, but at the same time was not as brittle as the former, so it could be rolled up, if necessary for storage.

EPOXY-POLYSULFIDES

Gel coat mixtures were also made using epoxy-polysulfide mixtures as shown below:

Shell Chemical Company Epon 828	100 pts
Thiokol Chemical Company LP-3	50 pts
Diethylenetriamine	8 pts

The surface optics using the above formulation were at first quite satisfactory. However, after three days room temperature curing, under pressure, a good deal of patternless distortion was found. Good adhesion was obtained from the polyester to the epoxy-Thiokol coating, however. The optics of the completed polyester-fiberglass parabola were quite poor.

In an effort to improve the epoxy-Thiokol gel coat optics a mixture was made up as given above, but in addition 325 mesh silica powder was added to the mixture in the ratio of 2 parts of resin mixture to one part of silica. Considerably improved optics resulted. However, the cured mixture was much too stiff and brittle to be considered. It did, nevertheless, emphasize the fact that heavily filled coatings would have less shrinkage, and less distortion than unfilled coatings.

URETHANES

A new urethane elastomeric gel coat material was also tested. This was Archer-Daniels Midland Arolast 8025-8540. Only fair optics resulted from an approximately 10 mil application. Adhesion to the Mylar surface was inferior to the polysulfides in that the coating could be readily peeled off. Adhesion of the polyester to the urethane was likewise only fair. No further work was done with this material.

POLYESTER GEL COAT

One of the drawbacks to the use of a heavy gel coat is the additional weight involved. A series of tests were therefore made to determine if the gel coat might be eliminated by using a fully cured, single layer, glass fabric laminate as a gel coat. The intent here was to obtain a hard tough layer which would still be flexible after curing because of its thinness and the natural flexibility of the cloth reinforcement.

The tests were made by first priming the Mylar with DuPont Number 46950 adhesive and then adding a single layer of polyester impregnated Number 103 (0. 001 inch thick) fiberglass fabric. The cured samples were indeed very flexible and showed very little evidence of distortion when pressures were kept constant. If the pressure were released, distortion then was evidenced. On repressurization to the identical pressure used for curing, however, no or very little distortion could be seen. Unfortunately when additional layers of impregnated Number 103 fabric were added distortion immediately commenced with the onset of gelation. It is surmised then that in curing, the polyester resin inevitably shrinks, however, when only one layer was involved the shrinkage stresses were not high enough to overcome the pressurization stresses. Therefore distortion does not show up until the pressure is released. On the other hand, several layers of polyester-fiberglass did produce enough stress to be readily visible even when the diaphragm was pressurized.

OPTICAL IMPROVEMENT TECHNIQUES

POLYESTER-GEL COAT TESTS

The results of the gel coat tests strongly indicated the need for the gel coat, both from the standpoint of improving the polyester laminate-to-Mylar adhesion and the final optics involved. Furthermore it was also established that the best flexible gel coats, with good adhesion to the Mylar, were the polysulfides and the epoxy-polyamide mixtures. A series of tests were therefore made to determine the techniques which would produce surfaces with the least optical distortion.

The tests were all run using the one and two foot diameter transparent fixtures. In these tests the Mylar was stretched and relaxed, and then examined through the fixture. If the surface appeared perfect optically, then the coating would be applied to the diaphragm. The effect on the surface could then be observed immediately, or as the cure progressed. As described above, samples were prepared by brushing and spraying, and coatings were applied as single heavy coats or as light multiple coats.

The results of these tests indicated that very little distortion appeared after application or cure of gel coats of either type when applied by brush or spray. Application of a heavy brush coat did, however, produce slight optical discrepancies in the form of brush marks. It was then concluded that substantially all the distortion, either as fabric pattern or as the "patternless" distortion, directly resulted from the cure of the polyester resin-fiberglass laminate.

Tests were then made to determine how and when the polyester reinforcing laminate caused the distortion. It was determined that if the gel coat were too thin and/or if the fabric next to the gel coat were too coarse a weave, the resultant cured mirror surface would show a definite fabric pattern. Both the fabric pattern distortion and the irregular distortion would appear as the polyester resin started to gel and cure. The conclusion then is that both types of distortion are related to the effects of resin shrinkage and the differential stresses set up among the resin and the glass fabric and the substrate. Figure 1 shows the reflection of the test grid in a two foot diameter typical polysulfide gel coat and polyester fiberglass reinforced parabola.

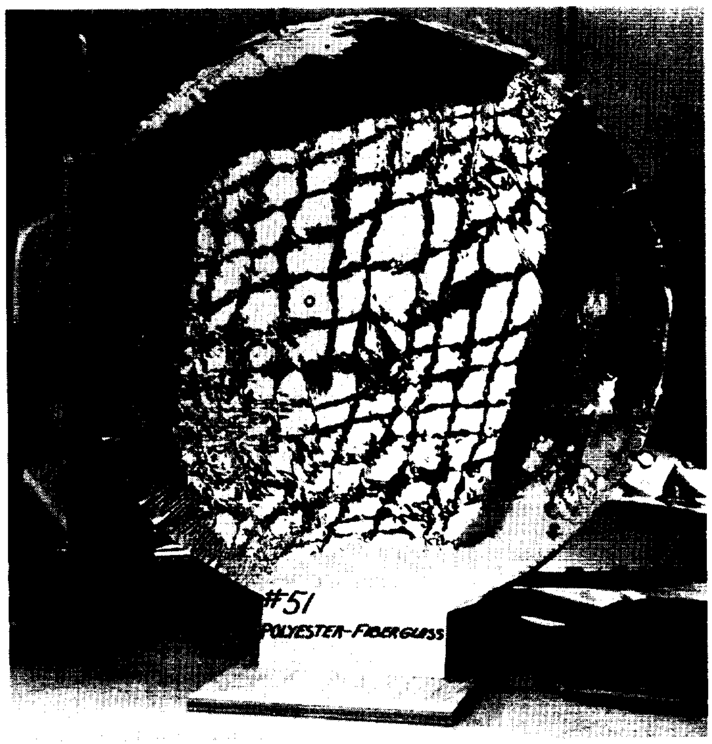

Figure 1. Two-foot diameter polysulfide-polyester-fiberglass reinforced parabola. (Two layers 181 fabric for reinforcement.)

The polyester resin used in all the above tests was American Cyanamide Laminac 4128, a styrene monomer resin. The resin was catalyzed with 1-1/2 percent methyl ethyl ketone peroxide and 1/2 percent cobalt napthenate to result in a room temperature gel time of approximately 30 minutes. The majority of the samples were filled with 325 mesh silica powder, in the ratio of one part resin to one part filler. The filler, of course, was used to reduce the shrinkage as much as possible. Tests were also made using unfilled resin, with however, 2 percent Cab-O-Sil to impart thixotropy. The filled resins in all cases appeared to show slightly less distortion, as expected. The serious disadvantage in the use of the heavily filled resin, however, was the additional weight imparted and the loss in strength and adhesion as the result of the excess filler.

In addition to the use of the Laminac 4128 resin a number of other polyester resins were tested, both from the standpoint of UV catalyzed reactivity and possible lower shrink rate. An attempt was made to obtain all three cross-linking monomer types of resins; i. e., styrene, diallyl phthalate and triallyl cyanurate so that comparisons might be made of the various types. The vendors were also requested to supply their lowest shrinkage materials. Emphasis was also placed on securing non-accelerated resins (Laminac 4128 contains 0.06 percent of cobalt napthenate accelerator as supplied by the manufacturer). The resins obtained for test are shown in Table II.

Resin	Source	Monomer
Laminac 4123	American Cyanamide Co.	Styrene
PDL-7-820-25-25	American Cyanamide Co.	Styrene
Laminac 4202	American Cyanamide Co.	Diallyl phthalate
Vibrin 158	Naugatuck Chem. Co.	Styrene
Vibrin 136A	Naugatuck Chem. Co.	Triallyl cyanurate
Hetron 103	Hooker Chem. Co.	Diallyl phthalate

Table II. Polyester resins tested.

The result of the tests indicated that the resins containing styrene monomer cured in approximately 20 to 30 minutes to a Barcol hardness of approximately 50 when catalyzed with a 2 percent benzoin-tricresyl prosphate mixture. The diallyl phthalate and the triallyl cyanurate monomer resins with the same catalyst took approximately three times as long to gel, and took approximately 24 hours at room temperature to reach a Barcol hardness of approximately 30. Additional tests are planned in which benzoyl peroxide and/or cobalt napthenate will be added to each resin in various amounts to accelerate gelatin. Preliminary tests with both of these resins did not indicate a significant reduction in the shrink pattern. (The DAP resins are claimed to show 30 percent less shrinkage than normal styrene monomer containing resins.)

EPOXY RESIN TESTS

Polyester resins as a class exhibit the highest cure shrinkage of any of the liquid thermosetting resins. By contrast epoxy resins show approximately one half the shrinkage of polyesters cured under similar circumstances. In tests run during the first quarter it was found that substitution of a room temperature curing epoxy resin for a polyester resulted in improved optics. The first epoxy tests were made using a "lock" fabric and a silica filled epoxy resin in conjunction with the polysulfide or epoxy-polyamide gel coat. Later tests were made using only unfilled epoxy resin and light weight glass fabric. See Figure 2.

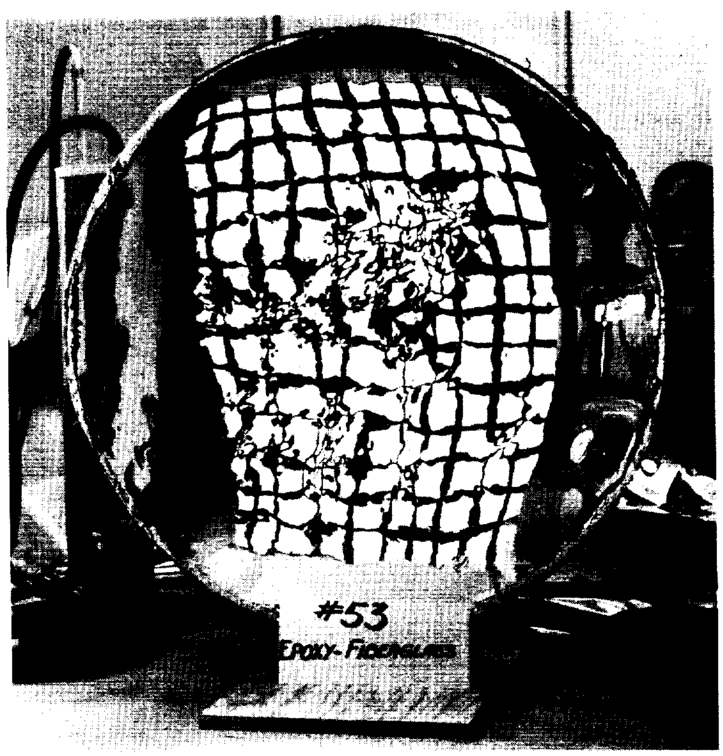

Figure 2. Two-foot diameter polysulfide-epoxy reinforced parabola. (Two layers 103 and two layers 181 fabric.)

The best of the epoxy-fiberglass samples utilized an epoxy-Versamid gel coat and six layers of Number 103 fiberglass fabric plus one layer of Number 120 fabric impregnated with Epon 828 resin, and room temperature cured with diethylenetriamine. This parabola was considerably superior to all previously made polyester rigidized parabolas, from the standpoint of optics. It was also considerably lighter in weight than the filled polyester parabolas having a weight of approximately 0.35 pound per square foot. The specular reflectivity on this sample was 82 percent and the irregular distortion was moderate and considerably less than on similar polyester rigidized parabolas. Measurements of the figure indicated it to be an irregular hyperboloid across one diameter and a paraboloid across another diameter 90 degrees to the first. Figure 3 illustrates the reflection of the test grid in this parabola. Similar tests made on a sample showing a fairly pronounced fabric pattern

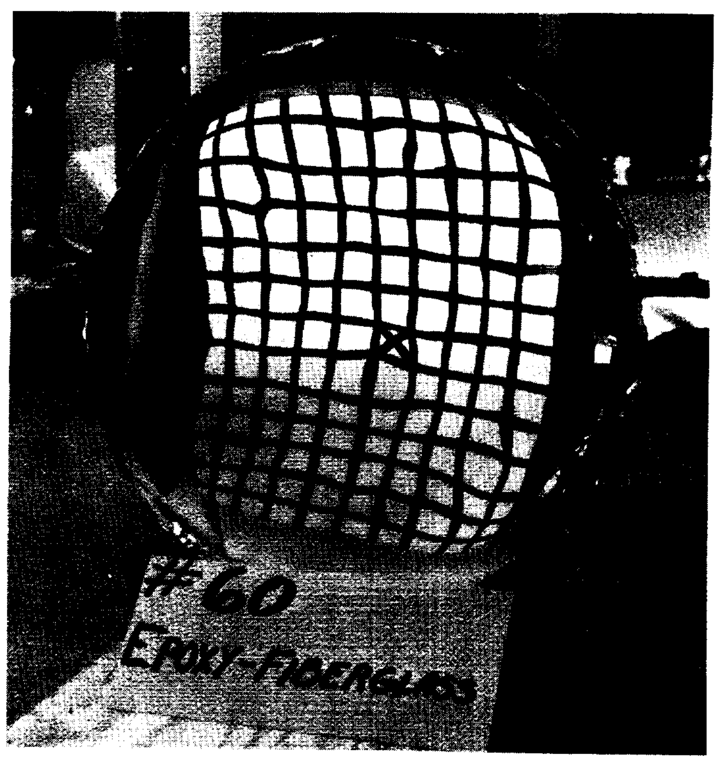

Figure 3. Grid reflection in one-foot diameter epoxy-Versamid and epoxy-fiberglass parabola. (Six layers 103 and one layer 120 fabric.)

showed a specular reflectivity of 77 percent and the figure was determined to be an oblate spheroid. The significance of these tests was that:

1. The epoxy resin apparently was considerably superior to the polyester being used.
2. The epoxy reinforced sample could then serve as a standard for subsequent polyester samples.
3. Simple visual comparison between two samples could be relied upon as a good approximate gage of quality.

With the initial success of the first epoxy resin parabolas it was decided to conduct several more tests to further explore the possibilities in the use of epoxy resins. In particular it was desired to ascertain the effects of omitting the glass fabric. Tests were made using six inch, one foot and two foot diameter diaphragms. In each case the reinforcement system consisted of simply a filled epoxy resin mixture made to the following formula:

Epon 828	—	100 pts
Gold Bond silica	—	60 pts
Cab-O-Sil	—	2 pts
Diethylenetriamine	—	8 pts

The resin mixture was applied to the Mylar surface which had been previously primed with one coat of DuPont Number 46950 adhesive. No gel coat was used since there was no fabric reinforcement. The results in all cases were exceptionally good from the standpoint of optics and Mylar adhesion. The grid reflections of a one and two foot parabola made by this process are illustrated in Figures 4 and 5.

The new system, while producing excellent parabolas from an optical standpoint, had several serious defects. First this system was considerably heavier than originally planned; i. e., the weight was approximately 0.54 pound per square foot instead of the 0.395 pound per square foot originally calculated. The other defect was the extreme fragility of the structure, since no fibrous reinforcement was used. This fragility made it almost impossible to handle the parabola, and in fact it was broken during normal handling shortly after being photographed.

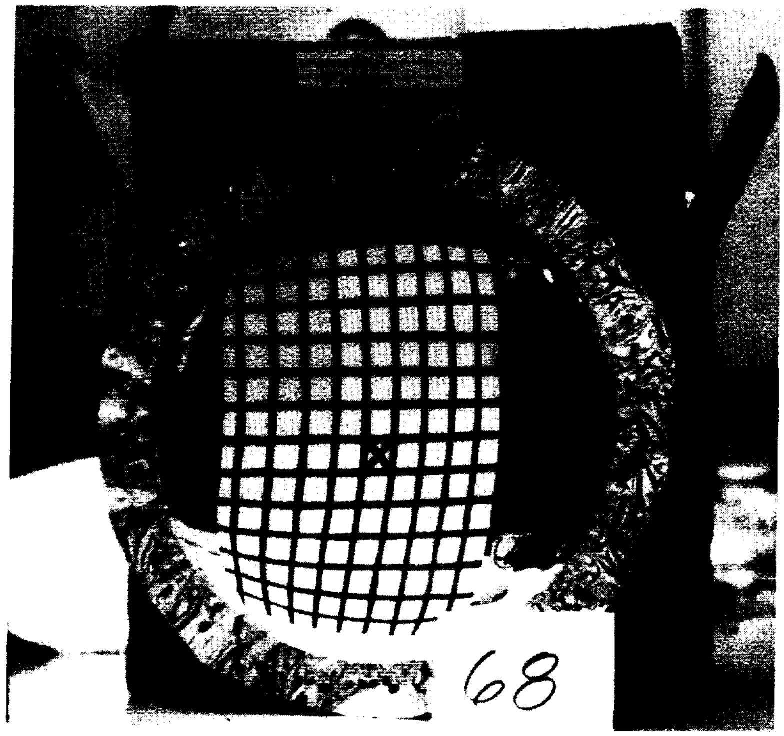

Figure 4. One-foot diameter epoxy-silica filled parabola.

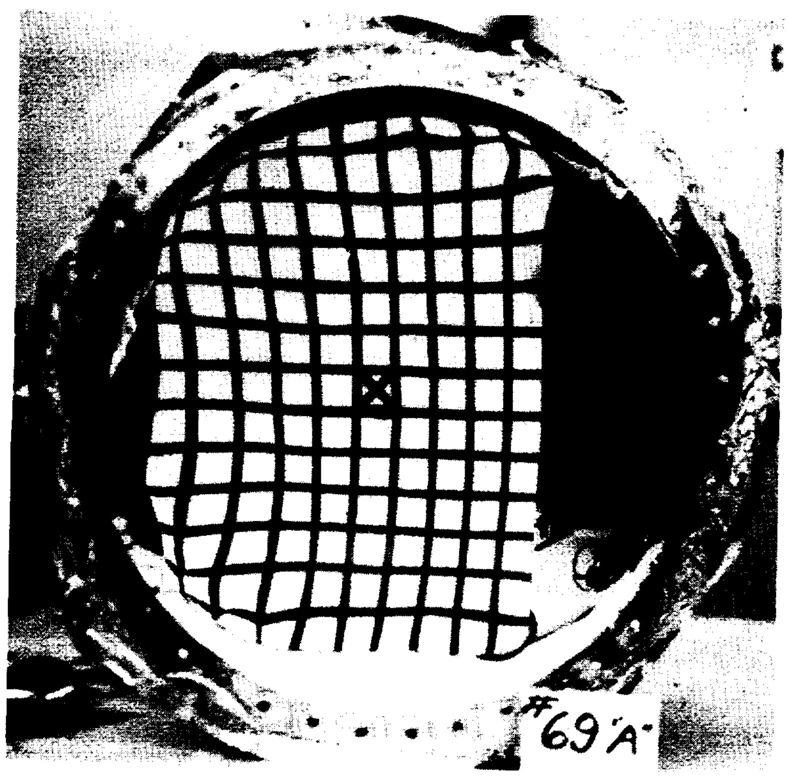

Figure 5. Two-foot diameter epoxy-silica filled parabola.

NON-WOVEN REINFORCEMENTS

From the above tests it was demonstrated that the use of a powdered filler would make a definite improvement in the optical surface obtained as compared to the use of a woven fabric reinforcement. However, because the powdered reinforcement structure was so fragile some type of fibrous reinforcement was considered absolutely necessary. Tests were made to disperse 1/16 to 1/8 Dacron and 1/8 inch milled glass fibers in thinned and unthinned resin. In each test it was not found possible to evenly disperse either fiber in the resin either by hand or by means of low speed or high speed stirrers. The fibers "balled up" and a smooth troweling mix could not be made in the few tests which were run.

Other types of non-woven reinforcements were also obtained. These included Lantuck non-woven fabrics from the Wellington Sears Company, a felt-like Dacron fiber material and Troytuf Dacron reinforcement from the Troy Mills, Inc. The latter material was a very loosely felted stock somewhat similar to the Lantuck materials. Only a few tests were made using the thinner (0.020 to 0.060 inch) materials, with the polyester resin impregnants. The optical results in each case were quite poor. The Dacron fibers also considerably inhibited the rate of cure by ultraviolet radiation.

VACUUM BAG TECHNIQUES

Another test made in an attempt to improve the optics of a gel coat-fabric reinforced parabola utilized a vacuum bag to place the impregnated fabric under pressure against the Mylar diaphragm. While it was realized that such a process would not be practical for actual space usage, it was considered worthwhile to determine if the application of pressure to the laminate would result in better optics. To further aid in improving the optics an epoxy resin was used as the fiberglass impregnant, along with the epoxy-Versamid gel coat. The laminate, when under pressure from the vacuum bag, was "rubbed out" using standard low pressure laminating techniques so that all air bubbles and wrinkles were worked out and uniform wetting was obtained.

The assembly was cured under pressure overnight. Distortion was observed to commence during the rubbing out operation, and after cure and release of pressure the surface showed a bad fabric pattern and distortion.

PHOTOGRAPHIC TESTS

With the production of the improved surfaces and figures, it was desired that a technique be developed for rapid inspection and comparison of the various parabolas produced. Accordingly a 30 x 40-inch grid chart was made showing 3-inch squares on a white background. The lines were made using 3/4-inch wide black pressure sensitive tape. With this chart comparisons of various parabolas could be made much more objectively than had previously been done. In addition, by means of a Polaroid camera records could easily be made of each sample. This process was then instituted for each of the later samples.

OPTICAL INSPECTION TESTS

During the first quarter of the project no tests were run to determine either the specular reflectance or the figure obtained, since all the samples were visually judged unsatisfactory. However, after development of the polysulfide gel coat techniques several samples were made which were considered adequate for test. These first samples were tested only for reflectivity, since development of satisfactory optical surfaces was considered of greater importance than emphasis on the figure. The configuration of the samples tested, and the results of the central six-inch diameter reflectance tests are shown in Table III.

Number	Size, in.	Configuration			Percent Reflectivity
		Gel Coat	Resin	Reinforcement	
31	12	EC-81	Polyester	2 layers 181	80.5
57	12	Epoxy-Versamid	Epoxy	2 layers 103 and 2 layers 181	77.0
60	12	Epoxy-Versamid	Epoxy	6 layers 103 and 1 layer 120	82.1

Table III. Results of specular reflectivity tests.

Several figure determination tests were also run on the most promising samples. It should be noted that the 12-inch diameter samples were formed using accurately determined pressures, whereas the 24-inch samples utilized pressures previously determined for 20-inch diameter parabolas. The results of the figure determinations are shown in the Appendix along with the methods of determining the reflectivity and the figure.

SYNTACTIC FOAM INVESTIGATIONS

EPOXY SYNTACTIC FOAM TESTS

After completion of the tests using the powdered filler reinforcements it was very apparent that the optical quality of these parabolas far surpassed any parabolas utilizing resin impregnated fiberglass. However, the extreme fragility and relatively heavy weight of the filled resin reinforcement definitely indicated that some other materials should be used.

In order to have the advantages of a powdered filler and still have light weight, phenolic microballoons were incorporated into the epoxy resin. Sufficient microballoons were added to the resin until a paste-like mixture resulted. This material then had the advantage of light weight and bulk to increase its stiffness. The formula adopted is shown below:

Epon 828	100 pts
Phenolic microballoons	23 pts
Cab-O-Sil	1.5 pts
Diethylenetriamine (DTA)	8 pts

The paste reinforcement was hand spread over the inflated Mylar, which had previously been primed with a thin brush coat of DuPont Number 46950 adhesive. The parabola was allowed to cure overnight at room temperature, at the relaxation pressure. Upon release of pressure, after 16 hours of curing, an extremely good part was secured. The parabola was very good from the standpoint of optics and excellent adhesion of the reinforcement to the Mylar.

Several six inch and one foot diameter parabolas were made using the above techniques, all with uniformly good results. Since the reinforcements were still not too strong after cure, tests were made to determine the feasibility of incorporating a single layer fabric reinforcement in with the syntactic foam. Two tests were run in which the fabric was laid on top of the paste and was slowly wet with resin as the material cured. In both cases the optics were considerably inferior to those samples made without the fabric reinforcement (see Figure 6). Another test made by applying a fabric to an already cured part (initially with excellent optics) resulted likewise in a considerable deterioration of the optical quality. This then conclusively demonstrates the role of the fabric in causing optical deterioration.

Figure 6. One-foot diameter epoxy-phenolic microballoon parabola reinforced with one layer of fabric.

The first samples using either the powdered filler or the microballoon filler were made by simply troweling the paste over the inflated dome. Since both materials were opaque and did not flow to any extent, it was found quite difficult to spread the paste to a uniform thickness. This lack of uniformity was clearly visible in the first samples, and in fact was the major defect in these otherwise very satisfactory parabolas.

In an effort to obtain more uniformity in the coating several paste spreading techniques were tried. A blade spreader method (doctor blade) using a spacer was not successful since the paste could not be spread evenly and would hang up in some areas and pull away in other areas. Another technique tried was a roller which covered the entire diameter of the membrane. By means of a ring spacer around the circumference of the membrane the paste could be rolled down and spread over the entire surface to a fairly uniform height. Using this technique, however, it was not possible to coat the inflated membrane. The Mylar was therefore coated in the flat condition and then subjected to the stretch and relaxation treatment with the paste in place. No appreciable effect was noted from the weight or resistance of the paste to the pressurizing treatment, and the parabolas made this way showed excellent properties both from the standpoint of the optical surface and the figure obtained (see Figure 7).

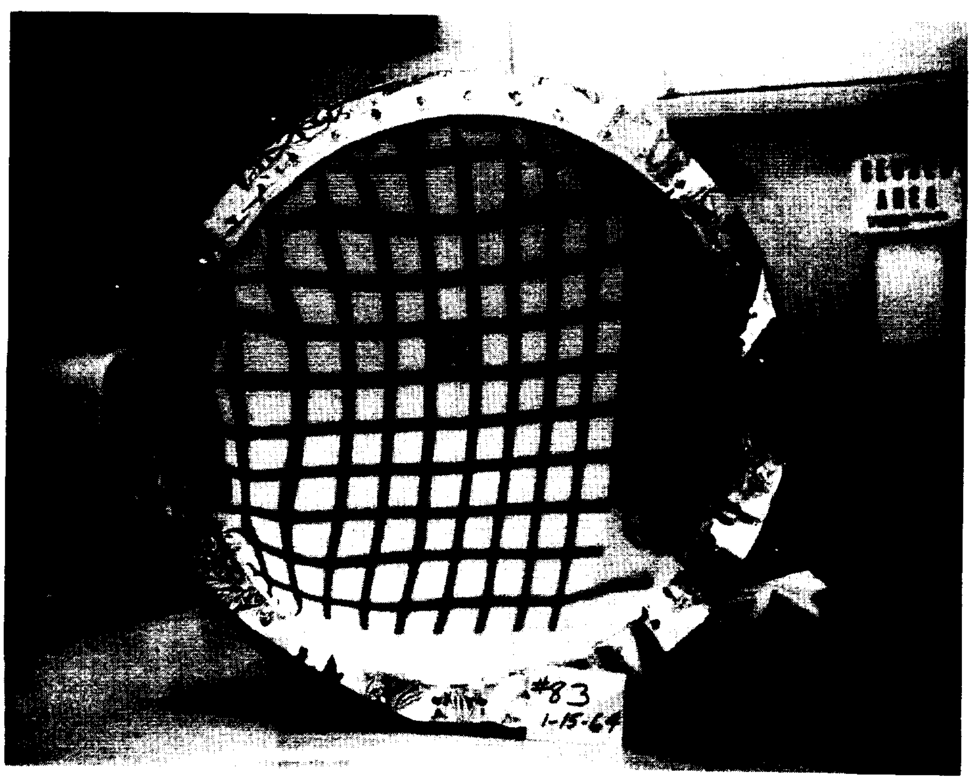

Figure 7. Two-foot diameter epoxy-phenolic microballoon parabola made with "flat" paste spread technique.

A third method tried for spreading the paste was to roll the material into a ball and then, using a one foot square flat plate and 0.093 inch spacers, press the ball into a thin disc. Because of the very adhesive nature of the paste it was not possible to do this on cellophane or other carrier and then transfer the disc to the Mylar. This would then have to be done on the actual part, which might limit the usefulness of this process for a five foot disc. The very high adhesiveness also presented a number of problems to the rolling process since the material tended to adhere to the roller. Various techniques of dusting and lubricating the roller were unsatisfactory. Placing a thin polyethylene film over the paste and rolling on top of the film made a partially satisfactory solution. However, removal of the polyethylene film presented problems in that portions of the paste were also removed. This technique is definitely not yet perfected.

The first tests made with the epoxy resin and the phenolic microballoons utilized a room temperature catalyst, diethylenetriamine, which allows a working time of approximately 30 to 40 minutes after being added to the resin-microballoon mixture. This was just enough time to allow thorough mixing and then subsequent spreading on the one foot diameter specimens. In attempting to spread approximately four times as much over the two foot diameter parabola it was found that the paste was starting to cure before spreading was complete. The catalyst was therefore changed to diethylaminopropylamine (Shell Catalyst A) which allowed a working time of 3 to 4 hours at room temperature, and did set up overnight. Mixtures catalyzed with this material, however, do not set up to full hardness until a 2 to 3 hour post cure at 180 to 240°F is used.

Only two tests were made in which a room temperature cured Catalyst A part was subjected to the post cure. In the first test the parabola was placed on a tray in an oven at 180°F. After approximately 1/2 hour the part was almost completely flattened, due in part to softening of the reinforcement and to residual shrinkage stresses in the Mylar. The second test was made with the parabola still in the forming fixture. The temperature in this test was brought up slowly and the pressure was adjusted so that there was no noticeable change in the height of the sagitta. Upon cooling and removal from the fixture it was found that approximately 15 percent of the Mylar had pulled away from the reinforcement, at the edges only. The center portion of the parabola showed good adhesion, with only fair optics. The optics had apparently deteriorated, however, during the heat treatment since the surface appeared excellent, when viewed through the fixture, just prior to the post cure (see Figure 8).

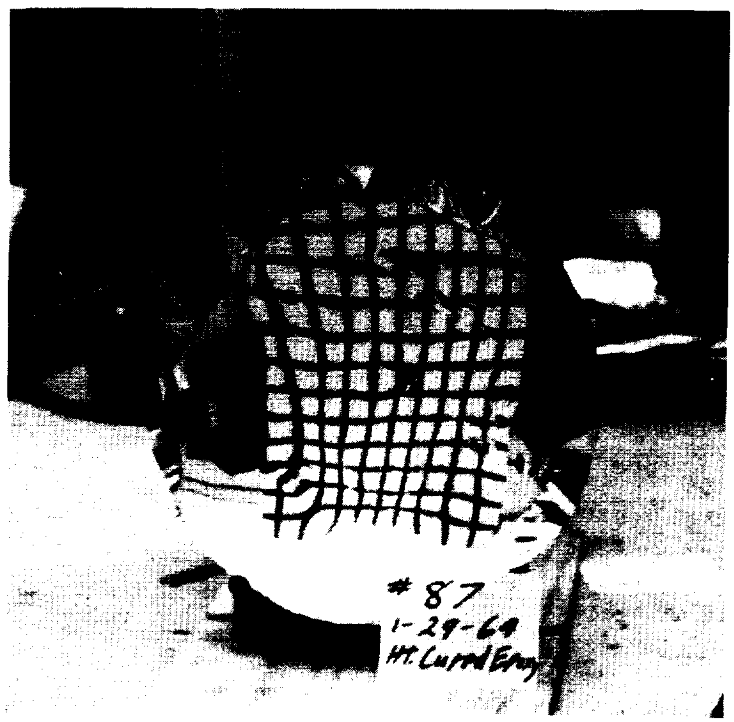

Figure 8. One-foot diameter epoxy-phenolic microballoon parabola after post cure heat treatment.

POLYESTER SYNTACTIC FOAM TESTS

With the very definite improvement shown by the use of the phenolic microballoons in the epoxy resin the same filler was incorporated into a UV catalyzed styrene monomer polyester resin. As anticipated practically no cure took place because of the opacity of the phenolic balloons. A similar mixture using glass microballoons (Emerson and Cuming Eccospheres) was somewhat better. In this case, after a long exposure to the UV radiation, a sample approximately 0.100 inch thick cured to a depth of approximately 0.030 inch. Based on these results then no further tests were made using microballoons to fill the UV catalyzed polyester resin.

STORAGE TESTS

In service the solar collector would have to be stored for some finite length of time, with the gel coat cured and an uncured rigidizing coat in contact with it. Therefore such a test was made using a 24 inch diameter parabola. One half the surface was coated with a polysulfide, Coast Pro-Seal Number 890, and the other half with an epoxy-Versamid coating. A "lock" fabric was applied over all but approximately one third of the epoxy coated surface. The sample was then stored for 72 hours, at room temperature, in a rolled up condition. On unrolling and repressurizing the diaphragm permanent wrinkles were found throughout the area covered by the "lock" fabric. These wrinkles persisted after the polyester rigidizing layer was applied. The section coated only with the epoxy-Versamid showed no wrinkles on repressurization and the polyester laminate showed good adhesion to the gel coat. As the result of these tests it was decided to concentrate on techniques which eliminated the "lock" fabric.

MYLAR TREATMENTS

SURFACE TREATMENTS

The storage tests described above indicated that the use of the "lock" fabric and gel coat might be detrimental to the final optical surface. Therefore a series of tests were initiated to develop a technique to etch the Mylar surface in order to improve the gel coat-to-Mylar bond, or perhaps to enable a reinforcement-to-Mylar bond to be made. It was found that a 75 to 95 percent sulfuric acid solution swabbed on the Mylar surface for 20 to 30 minutes at room temperature would etch the surface. Somewhat the same results could be obtained using fine emery paper. In simple peel tests using polyester resins very inconsistent results were obtained. Since this process was considered somewhat impractical for a large surface, no further work was done at this time.

HEAT TREATMENTS

The first post cure tests of the parabola indicated that the Mylar definitely had shrinkage stresses in the material which were brought out by the heat treatment. To relieve these stresses the Mylar was subjected to a number of heat treatments for 3 to 6 hours at temperatures varying from 240 to 300°F. No visual effect on the reflective surface was seen after prolonged heating. There was, however, a dimensional change of approximately 1-1/2 percent in the lengthwise direction and approximately 1 percent in the width direction in the short duration tests run. Tests are being continued at 275°F to determine the period of time required to bring the material to equilibrium. It is then planned that "pre-shrunk" Mylar would be used for the parabolas.

MOSAIC TESTS

The mosaic samples were received from the G. T. Schjeldahl Company and one was mounted in the test fixture to determine the correct pressures for the stretch and relaxation process.

The sample received was of mediocre quality, having several pin hole leaks and a great number of folds and erases. It was, however, mounted and pressurized, and the leaks were stopped with scotch tape, after which an EC-801 polysulfide coating was applied. In order to thoroughly cure the coating the parabola was kept under pressure for several days at the desired pressure of 17 mm of Hg. It was found impossible to accurately maintain this pressure over this period of time using the plant air supply and an ordinary air pressure regulator, and a small bleeder. Consequently two special regulators have been procured; one a 0 to 30 psi regulator, which will be used to drop the 100 psi plant air down to 10 psi, and a second, 0 to 2 psi regulator, will be used to actually pressurize the parabola. With this combination it is believed that satisfactory pressure regulation will be achieved.

FUTURE PLANS

For the next quarter it is planned that the following items will be investigated:

1. Additional tests will be made of the polyester resin systems to develop the optimum system.
2. The mosaic tests will be initiated to determine techniques for coating and rigidizing the five foot diameter parabolas.
3. Thermal, mechanical and radiation tests will be made on samples of the optimum system.
4. Erection and rigidization tests of the full sized, torus erected parabolas will be initiated.
5. Pending approval by NASA, additional work may be performed on the epoxy-microballoon system, if possible within the financial and time limitations of the contract.

APPENDIX

The techniques for determining the specular reflectivity and the figure of the parabolas are as follows.

REFLECTIVITY TESTS

For these tests an accurate standard spherical mirror was obtained. Figured to an accuracy of plus and minus 1/8 wavelength (NaD) and coated with plain aluminum of astronomical quality, this standard mirror will reimage a small source placed at its center of curvature at almost exactly 90-percent reflective and imaging efficiency. For very precise work the reference standard mirror can itself be calibrated.

A small source aperture is next illuminated uniformly and the reimaged spot,using the entire standard mirror aperture, is allowed to fall on a suitable sensor-meter combination. Similar measurements are then made using the test reflector of unknown quality. By comparing the meter readings for the standard and test mirrors, and allowing for the difference in the solid angle used with each, the reflectivity of the test mirror can be deduced.

RADIUS OF CURVATURE TESTS

This test can serve for an accurate, quantitative evaluation of the gross figure of a reflector. The test equipment consists of a sensible-sized source with an image card adjacent to it, moving together on a track parallel to the optical axis. A mask is placed over the collector and various zones are exposed in turn to the source. The zones' individual axial radii of curvature are measured by finding the position of the image card-source when the reflected ray intersects the optical axis at the source position. The central zone's radius of curvature is determined by finding the position of best focus.

A plot can then be made of the departure of the various zones' radii of curvature – from that of the central zone – as a function of each zone's radial distance from the center of the reflector under test. This plot can be compared with the predicted differences for various reference conics of revolution. The angular deviation of the various zones of a near paraboloid can be deduced from the above measurements by using simple trigonometry.

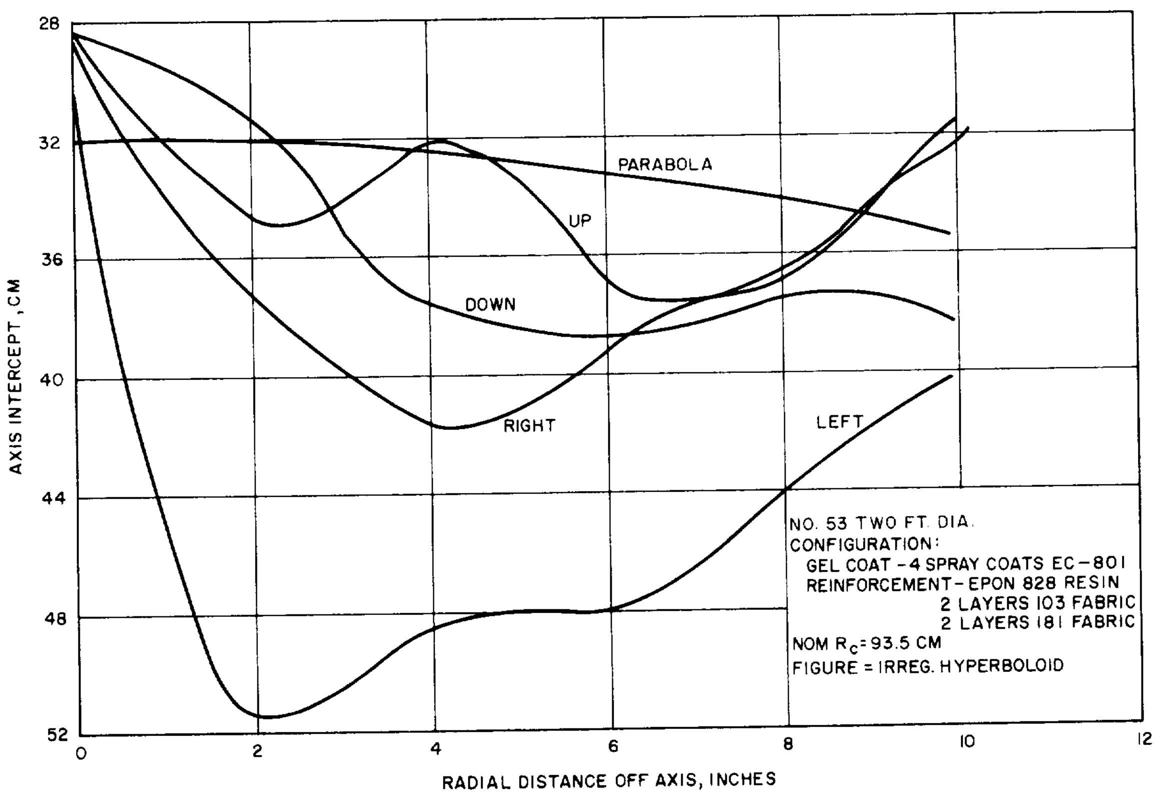

Figure 9. Figure determination of various parabolas.

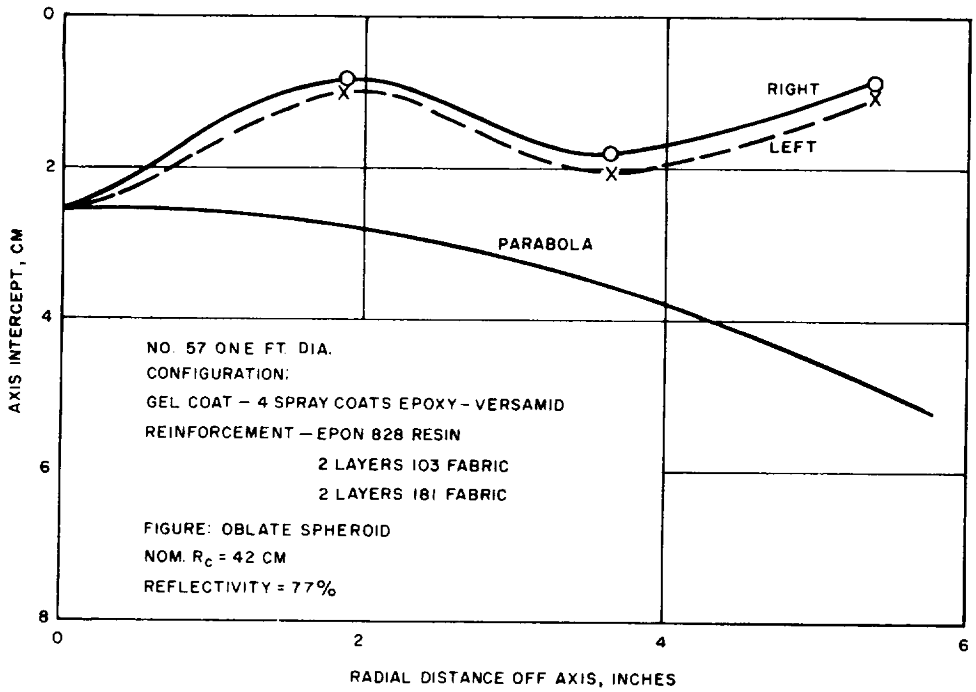

Figure 10. Figure determination of various parabolas.

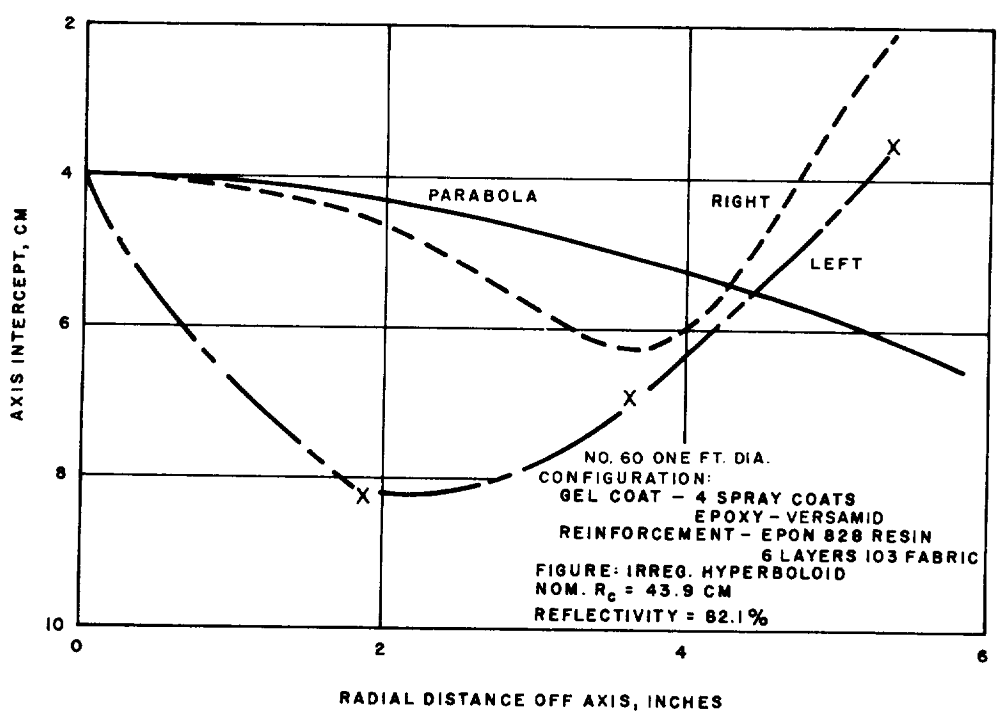

Figure 11. Figure determination of various parabolas.

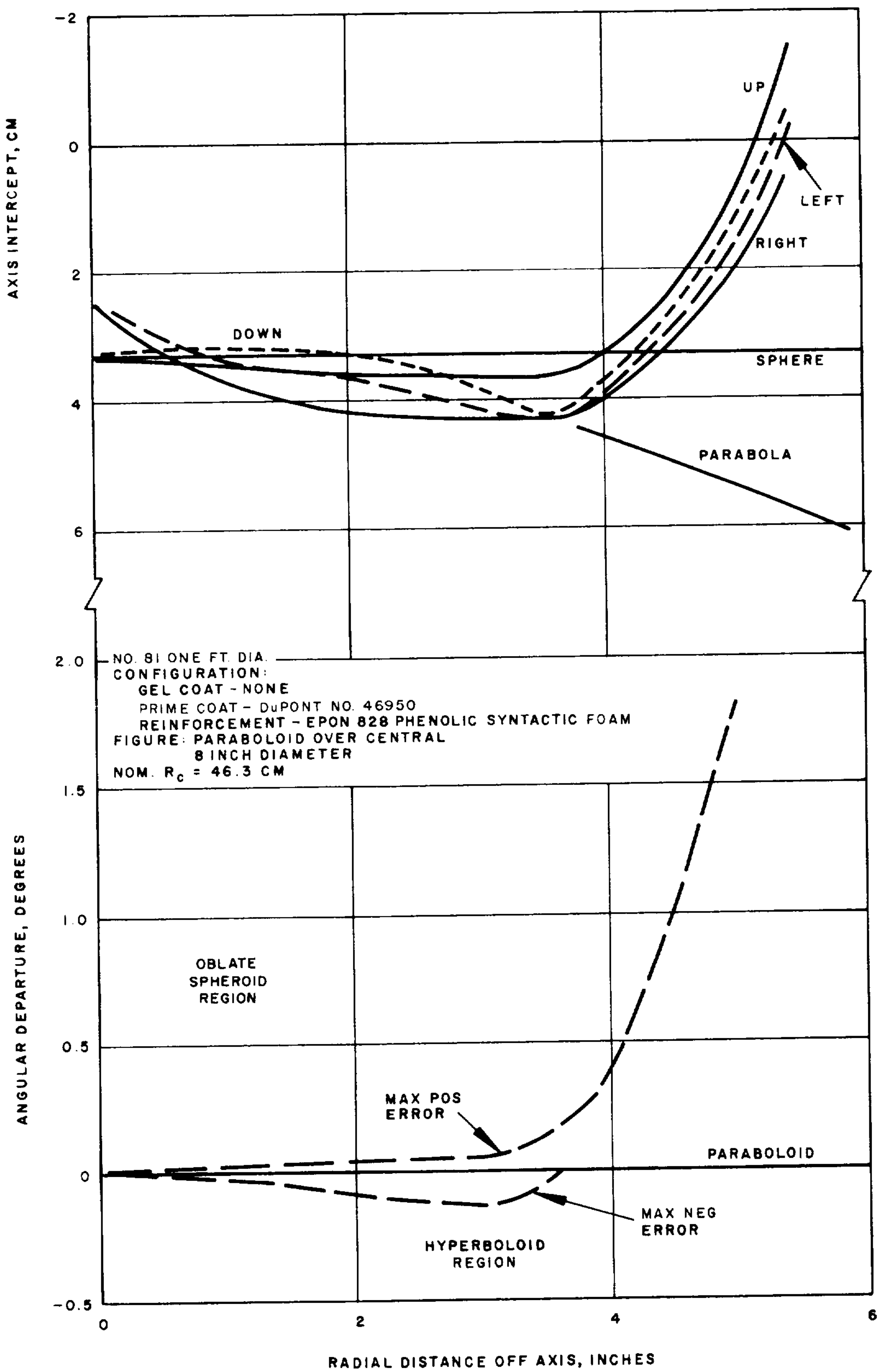

Figure 12. Figure determination of various parabolas.

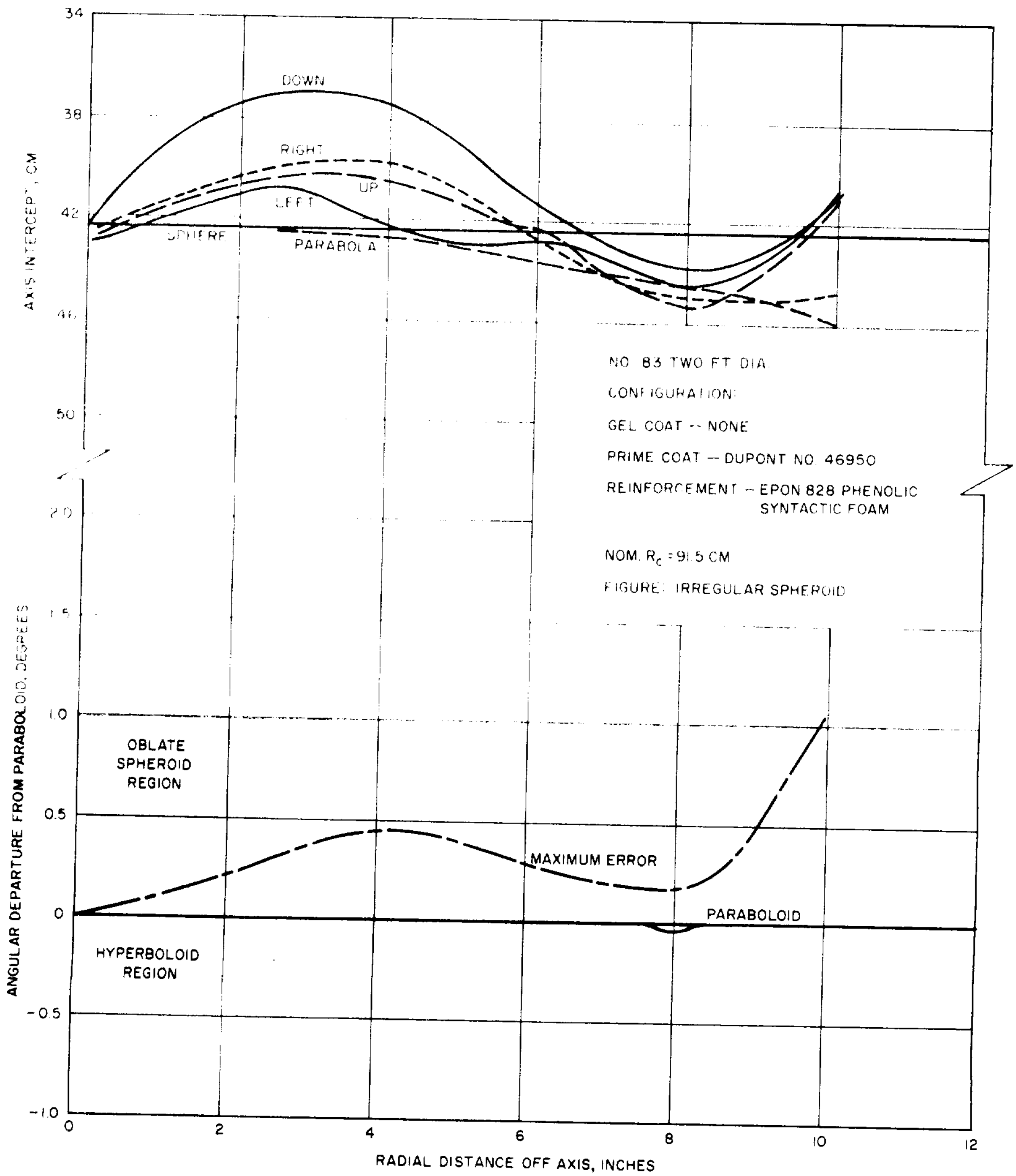

Figure 13. Figure determination of various parabolas.

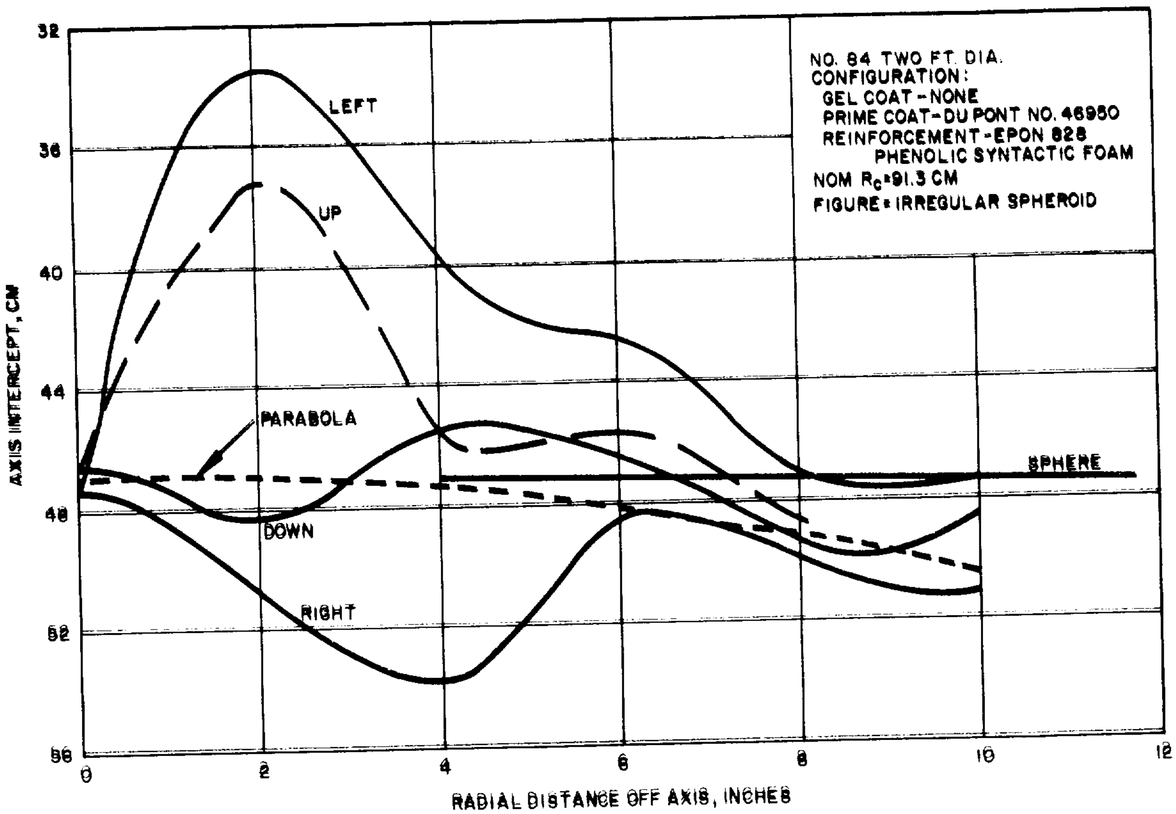

Figure 14. Figure determination of various parabolas.